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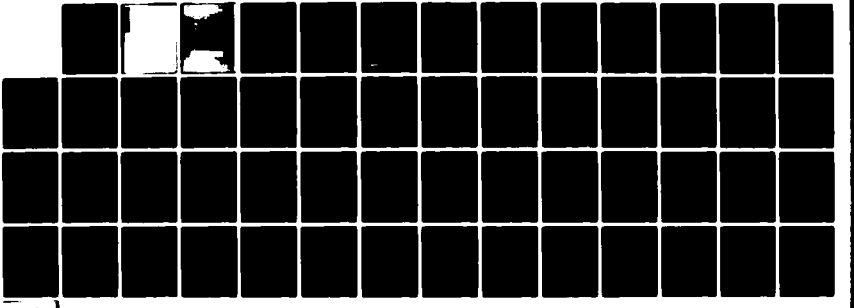

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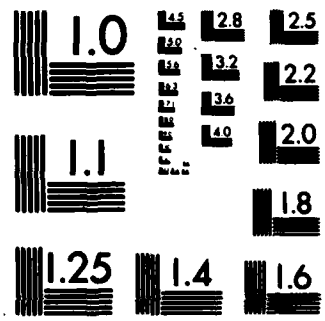

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This Rand Note reviews mechanisms of escalation that should be included in the work of the Rand Strategy Assessment Center (RSAC), and discusses alternative ways of doing so analytically. It assumes that the reader is familiar with the RSAC's objectives, technical approach, and terminology. The appendix discusses some of these matters briefly. The Note begins by discussing the relationship between escalation for direct military benefit and escalation as a form of generalized bargaining in the sense of Schelling. It then identifies six important factors causing escalation to become difficult to control. Having outlined the escalation issues to be addressed and some of the relevant variables to be included in RSAC exercises, the Note considers two analytic techniques for doing so: formal decision analysis and heuristic rule-based modeling. The Note concludes that decision analysis may be invaluable for developing and evaluating rules even if little vestige of formal analysis will exist explicitly in most of the final Red and Blue Agent programs.

A RAND NOTE

TREATMENT OF ESCALATION IN THE
RAND STRATEGY ASSESSMENT CENTER

Charles Glaser, Paul K. Davis

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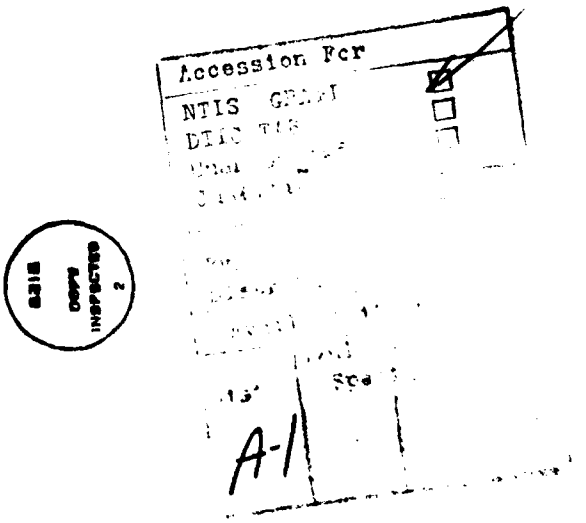
PREFACE

This Note was prepared for the Rand Strategy Assessment Center (RSAC) as part of a program supported by the Director of Net Assessment in the Office of the Secretary of Defense, and by the Defense Nuclear Agency under Contract No. DNA001-80-C-0298. The principal author, Charles Glaser, served as a Rand summer intern in 1982 before returning to Harvard's John F. Kennedy School of Government to complete his doctorate. Comments and inquiries are welcome. Please contact Dr. Paul K. Davis, Director of the Rand Strategy Assessment Center.



SUMMARY

This Rand Note reviews mechanisms of escalation that should be included in the work of the Rand Strategy Assessment Center (RSAC), and discusses alternative ways of doing so analytically. It assumes that the reader is familiar with the RSAC's objectives, technical approach, and terminology.[1] The appendix discusses some of these matters briefly.

The Note begins by discussing the relationship between escalation for direct military benefit, and escalation as a form of generalized bargaining in the sense of Schelling. It then identifies six important factors causing escalation to become difficult to control. These involve: (1) the desire to win (or at least not to lose); (2) the increase in perceived stakes as war goes on; (3) crisis instability and escalation instability rooted in force postures; (4) misunderstandings and misperceptions; (5) fatalism (and attitudes about the natural momentum of war); and (6) poor communications. The relative importance of these factors is very different in Western and Soviet thinking, a theme touched on here and being explored in a separate paper.

The desire to reflect these considerations in RSAC work has significant implications for the design of automated players (the Red and Blue Agents), including the need to make the players sensitive to variables and uncertainties usually ignored in strategic modeling. The Note discusses the principal variables at issue as well as other design questions such as scenario plausibility, the completeness of experiments attempting to cover a range of scenarios, and simulation realism. The analysis observes that it may be more important to seek plausibility and completeness than to strive for simulation realism. By this we mean that while it is clearly important to understand the range of event streams (scenarios) that might unfold, it *may* be less feasible to predict accurately the cause-effect relationships behind individual events because the uncertainties are so large that a given situation, as seen at high levels, can lead to drastically different outcomes.

[1] See Paul K. Davis and James A. Winnefeld, *The Rand Strategy Assessment Center: An Overview and Interim Conclusions About Utility and Development Options*, The Rand Corporation, R-2945-DNA, March 1983.

Having outlined the escalation issues to be addressed and some of the relevant variables to be included in RSAC exercises, the Note considers two analytic techniques for doing so: formal decision analysis and heuristic rule-based modeling. It discusses in some detail the suitability of decision analysis and demonstrates how the various escalatory mechanisms could be treated in an RSAC framework using decision analysis. It also considers how to reflect variations in decisionmaker temperaments and suggests analytic ways to define and encompass adventurous and risk-taking behavior. Overall, we conclude that decision analysis can be a powerful research tool for RSAC work because of its structure, rigor, suitability for assessing analytic completeness, ability to handle uncertainty, and ability to reflect a range of decisionmaking behaviors. Indeed, there is no way to *avoid* using what amount to decision trees with subjectively assigned probabilities on such matters as Red's assessment of the likelihood of Blue's preemptive use of battlefield nuclear weapons.

There are also important liabilities to the usual decision analysis approach, some of them technical and some of them subjective. For example, there is a natural reluctance to base strategic analysis on models containing relative "utilities" for different outcomes of general nuclear war. It is also doubtful that automated players using a formal and complex decision-analysis approach would be realistic. To the contrary, real-world decisionmakers depend on dimly perceived heuristic rules mixed with a modest amount of formal logic. The RSAC is well-suited to using such heuristic rules, and does so already at different levels of complexity. The challenge, it would seem, will be to develop rules that are sufficiently sophisticated to represent some of the complexity of real national decisionmaking. The Note concludes that decision analysis may be invaluable for developing and evaluating such rules even if little vestige of such formal analysis will exist explicitly in most of the final Red and Blue Agent programs. As noted above, one vestige that will remain is the use of decision trees and subjective probabilities for top-level decisions. It is unlikely, however, that the RSAC will want to have the criteria for choosing among branches depend on explicit "utilities."

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I. INTRODUCTION

The Rand Strategy Assessment Center (RSAC) is an ambitious attempt to improve strategic analysis by combining the best features of war gaming and analytic modeling. By replacing human teams of war games by models, it is possible to explore numerous situations in some depth, and to do so reproducibly. This Note assumes familiarity with the RSAC's general approach.[1]

Given its emphasis on strategic conflict and the implicit role of strategic weapons at all levels of conflict, the RSAC *must* treat escalation effectively to achieve its basic objectives. What the RSAC can offer is a model that, once basic assumptions are made, can determine the course of an entire conflict--relating decisions and events at one point with events and options at later points. A major element in doing so will be the escalation model responsible for deciding under what conditions the limits of the conflict will change. Escalation has been studied extensively by strategists and, to a lesser extent, by historians. The RSAC presents an opportunity to apply the results of this often abstract work to a complex and relatively realistic framework.

The objectives of this Note are to:

- briefly review escalation theory and identify the variables to which decisionmakers are sensitive;
- describe the requirements the RSAC escalation model should satisfy;
- identify the major technical options, which involve decision analysis and use of heuristic rule-based models;
- examine how a decision analysis model could incorporate the important aspects of escalation; and

[1] Davis and Winnefeld (1983). Also see the appendix, which summarizes key elements of the RSAC's automated war gaming.

- compare the options in terms of RSAC requirements and suggest a basic approach involving one or both of decision analysis and rule-based modeling.

Although the thrust of this Note is primarily abstract and methodological, the approach taken by the RSAC in modeling escalation will have important implications for near-term research and subsequent applications to strategy problems.

With this introduction, then, Sec. II provides a brief review of escalation theory, Sec. III defines issues for RSAC development, Secs. IV and V discuss possible use of decision analysis in the RSAC, and Sec. VI compares the decision analysis approach with that of heuristic rules and suggests a hybrid approach.

II. A SELECTIVE REVIEW OF ESCALATION THEORY

WHAT IS ESCALATION? [1]

The first step in developing a model of escalation is to define terms. Escalation is often used to mean increasing the intensity or expanding the area of conflict. A problem with this definition is that it is independent of context. Schelling's work on bargaining within conflict provides the basis for more discriminating alternatives emphasizing the concept of limits.[2] Schelling has argued persuasively that because much of the bargaining over the limits of a war is tacit, the limits must have certain special characteristics. Referring to the pattern of actions through which limits are offered to the other side as a proposal, Schelling has written that

> The proposals have to be simple; they must form a recognizable pattern; they must rely on conspicuous landmarks; and they must take advantage of whatever distinctions are known to appeal to both sides. National boundaries and rivers, shorelines, the battle line itself, even parallels of latitude, the distinction between air and ground, the distinction between nuclear fission and chemical combustion, the distinction between combat support and economic support, the distinction between combatants and noncombatants, the distinctions among nationalities, tend to have these "obvious" qualities of simplicity, recognizability, and conspicuousness.[3]

If we adopt this idea of what can constitute a limit, then defining escalation as crossing a limit eliminates the issue of how large a step must be before it is considered escalatory (a problem with the first definition mentioned).[4] That escalation takes place in discrete steps

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[1] This review draws heavily from the works of Schelling (1960 and 1966). A useful summary of the existing theory on escalation and why it is difficult to control is presented in Smoke (1977).

[2] This Note does not discuss separately Western and Soviet models of escalation, taking instead a more general approach. However, the asymmetries in thought appear to be quite strong. A Soviet-style model is under development for the RSAC by Peter Stan.

[3] Schelling (1966), p. 137.

[4] This point is made by Smoke when he decides on a working definition for his empirical studies, p. 32.

follows from the characteristics of limits. The particular limit that is crossed, rather than the size of the step taken in crossing it, will determine the significance of the change in the nature of the conflict.

This understanding of escalation in terms of limits is compatible with our task of modeling results of high-level decisionmaking. It emphasizes strategic considerations which are usually in the realm of responsibility assumed by the higher-level command authority.

MOTIVATIONS FOR ESCALATING

When considering whether to escalate, there are two separate but related components of the action for the decisionmaker to consider: (1) the direct military value of escalation; and (2) the effect on the opponent's will and perceptions (i.e., communication of resolve and a willingness to accept greater risk). The second is a form of *bargaining*. The direct and bargaining components are often closely related.

The requirement that limits be recognizable is fundamental to the bargaining component of escalation. By choosing to cross a limit the decisionmaker believes the enemy recognizes, it is possible to communicate and thereby change the opponents expectation about the future of the conflict. At any point in a limited war, each protagonist is confronted with the risks of future escalation (both the possibility of further escalation and the consequences thereof) and realizes that the enemy is also. Deciding to escalate can demonstrate a willingness to accept the larger--partially unknown--costs that will be incurred at the new level of conflict, and to confront the possibility of further escalation from the new level.

Thus, there are two different bargaining-related motivations for escalation. First, a party may escalate to *convince the enemy of his resolve*. If successful, this may make termination more attractive to the enemy. Second, a party may escalate to put pressure on the enemy by increasing the level of violence and increasing the likelihood of still further escalation. This strategy, one intended to *raise the level of risk* rather than to show resolve, makes most sense if it seems the enemy would be more adversely affected by the higher level of risk.

A decisionmaker could escalate both to communicate resolve and to apply pressure by increasing the level of risk. And to a substantial extent the two motivations are related, since the decisionmaker knows that future assessments by the enemy of his resolve will take into consideration this escalation, independent of what had been the decisionmaker's motivations. It is this combination of the ability of both countries to increase the risk of further escalation and unlimited war, with the communications that accompany the escalation, that Schelling captures when he describes escalation as a "competition in risk taking."[5]

SOVIET VIEWS

The preceding discussion focused on bargaining, but as noted at the outset, the other major motivation for escalation is direct military benefit. It is this aspect that is unambiguously emphasized in Soviet writings. Although the Soviets are well aware of Western writings on escalation as bargaining, they appear to be manifestly unimpressed. As a minimum, they reject a focus on bargaining in war planning or declaratory policy because it runs counter to their emphasis on gaining and retaining the initiative with *decisive* action. It is a more speculative issue whether Soviet leaders in actual conflict would find a bargaining-related behavior more attractive than before conflict.[6]

WHY ESCALATION CAN BE HARD TO CONTROL

There is a common notion that escalation is at least partly beyond the control of the decisionmaker, and that once the initial decision to escalate is taken, the conflict develops an upward momentum of its own. Since the decision to escalate must be made by someone, presumably in most cases the national leadership, the notion is not literally correct.

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[5] Schelling (1966), p. 166.

[6] One of the most thoughtful discussions on these matters, which also contains references to the Soviet literature, is provided in Chapter VII of Leites (1982). As Leites notes, however, the Soviets simply do not discuss publicly or semi-publicly the sensitive aspects of deterrence versus war fighting. See also: Ermarth (1978); Lambeth (1981); and Lambeth (1978).

However, it is true that the pressures on decisionmakers can become so strong that the decisionmakers feel they have little control. To model escalation, then, we need to identify what it is about limited wars that make it difficult to maintain the limits. The factors examined in this Note are:

- Desire to win the war (or at least achieve an acceptable outcome).
- Increasing stakes.
- Objective instabilities.
- Misunderstandings and misperceptions.
- Fatalism.
- Physical communication problems.

These are examined one by one in what follows. Although the list may not be complete, it seems to capture most of what has been raised in the literature, including the literature on Soviet thought.

1. Desire to Win the War (or at Least to Achieve an Acceptable Outcome)

In some cases it seems clear to one party that escalation at least has the plausible potential for improving war outcome. Even though enemy counterescalation is possible, the certainty of losing in the absence of escalation can obviously increase willingness to accept greater risks.

The decisionmaker's image of his opponent will strongly affect his willingness to escalate to win the war. If he assumes the enemy will not counterescalate, then escalation will look more attractive than it may be in reality. Or, in a more complex calculation (if he does such conscious calculations), he may assume an action-reaction cycle stopping with the enemy's counterescalation to a level that is still tolerable and that still produces victory or net improvement over the present course of action. Such a calculation or "look-ahead" could involve any number of anticipated action-reaction cycles. So long as the initiator assumes he knows the enemy's countermoves, however, he is likely (though not certain) to be underestimating the true danger of escalation.

To better appreciate this chain of events, let us consider the role of uncertainty. In looking ahead, one does not know the enemy's reaction or the number of escalatory cycles. Thus, the decisionmaker is faced with a broad spectrum of outcomes, many of which are likely to be very undesirable. Due to the problem's complexity, some decisionmakers may use a best estimate model or look only a limited number of steps into the future. Others may try to avoid undesirable escalation by making highly risk-averse decisions. Still others, aware of the enemy's uncertainties and risks, may escalate or take seemingly imprudent actions to apply pressure. This is a "threat that leaves something to chance."[7] If a decisionmaker does simplify his decision in a way that underestimates future danger, whether by ignoring the possibility of counterescalation, by neglecting to pay attention to uncertainties, or by overlooking low probability events, then escalation will often (but not necessarily) be more likely.

As the authors were reminded by Jonathan Cave in a review, a rational decisionmaker could also have a strategy that--in effect--*overstated* the likelihood of enemy responses. He might, for example, choose a course of action that minimizes the likelihood of the worst possible outcome (e.g., complete defeat in general nuclear war) at the price of assuring a bad (but not worst) outcome. So, for example, if enemy nuclear preemption--even if not the best estimate--would be catastrophic, the decision could be to go first with nuclear weapons even though that would assure massive destruction to both sides.

2. Increasing Stakes

Losses may strengthen one's resolve to prevail. This is related to the phenomena discussed above but has some extra features. For example, because of costs already incurred, there may now be a desire for a better outcome than that required before conflict began. Thus, a country that fights to defend the status quo may find returning to that condition unacceptable as an end point.

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[7] Schelling (1960, pp. 187-203) describes in detail threats in which the final result of carrying out the threat is at least partially beyond the control of the threatener.

Moreover, once a country becomes involved in a war, it knows that the outcome will affect its international prestige. The larger its military and foreign policy commitment to the war, the greater the likely effect. Relevant here is the common belief that losing a war, or not stopping an ally from losing one, sets a dangerous precedent which may result in future costs by encouraging adversaries to be more adventurous in the future. Accepting this tenet provides a rationale not only for getting involved in certain wars, but also for achieving a satisfactory outcome even when the potential costs far exceed those justified by the immediate national security interest. The result can be to suck a nation[8] into a quagmire of disaster.

3. Objective Instabilities

Let us consider in turn the two principal types of instabilities that can affect decisions to escalate.

Crisis Instabilities. We shall say that a structural crisis instability exists if there is a significant objective advantage to escalating before the adversary escalates.[9] Such an instability can result in escalation even when both sides would prefer that there be no escalation. As the level of conflict increases, a decisionmaker's estimate that the enemy will escalate to higher levels may increase. If there is significant advantage to escalating first, then this will raise pressures to escalate--pressures increased further by the realization that the enemy probably wants to avoid being preempted and probably believes such a preemption is being considered (which it is). Hence, a race to preempt.

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[8] The prestige issue may become intertwined with domestic politics. Having gotten into a war, it may be politically costly to change objectives or admit error.

[9] We emphasize "objective" here to distinguish this case from that treated in subsection (1.). The word "structural" is a reminder that for the instability to actually produce escalation, it is necessary also that there be some reasonably perceived likelihood that one or the other side will in fact escalate. If there is enormous penalty for both sides in escalation, then a smaller (albeit significant) advantage in going first rather than second will not obviously be a decisive factor--unless one side believes that, in spite of "reason," the other side is likely to escalate.

This problem has been dealt with extensively at the strategic nuclear level in studies of incentives for counterforce first strikes. But the possibility for structural crisis instabilities is not limited to the strategic nuclear level. For example, decisions to mobilize troops to deny the enemy the advantage of mobilizing first or use conventional forces before they are destroyed by other conventional forces can be fueled by the same concerns.

The existence of structural crisis instabilities adds to the image that escalation is likely to get out of control. Once the conflict reaches a certain level a decisionmaker may feel compelled to escalate further. So may the adversary in reaction. There may be a need to make decisions quickly so the opportunity to preempt or to use one's forces is not lost. Time pressures may reduce one's ability to pursue diplomatic options and non-military bargaining, and may increase the chances of poor decisions or mistakes. These effects of time pressure in combination with the incentives to be the first to escalate produce an image in which decisionmakers no longer control the escalation process.

Escalation Instabilities. Escalation instabilities exist if one country can escalate to a level where the enemy does not have an "appropriate" response. This may reduce the risks of escalation, thereby increasing the incentives to escalate.[18] Once a conflict reaches a level close to this form of instability, the country with the additional escalatory options may see relatively few reasons not to escalate. It has been argued that one country's reliance on a "massive retaliation" or MAD postures, that is, the lack of flexible nuclear options, would create such a situation. If, for example, one country could perform limited strikes, knowing that the enemy's only response would be a massive nuclear attack, then the limited nuclear strikes could be used more effectively and confidently to achieve its political objectives than if the enemy had similar options.

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[18] Predicting the effect of the instability is complicated by the fact that the likelihood of an "inappropriate" response may be enhanced by the absence of a better one. Again, credibility is a key issue.

4. Misunderstandings and Misperceptions

The limits the warring countries can place on the conflict depend on their ability to agree to or at least recognize the limits available. If the countries have different understandings of what the established limits are, then the country with the less stringent view may unknowingly cross the line.

A familiar example here is theater nuclear forces. Soviet military doctrine maintains that if a conflict goes nuclear beyond the battlefield stage, it is unlikely to matter whether theater or central systems were being employed, and that it is unlikely that the conflict could be limited to the European theater.[11] U.S. strategists have tended to place greater stress on the theater/central system distinction and to view the escalation from theater to central war as less continuous and more controllable. Another example of potential confusion over intended limits could exist in the strategic nuclear counterforce-countervalue distinction. A large counterforce attack could include strikes against bomber bases, submarine ports, and possibly C^3. While the attacker might envision carefully prescribed constraints, the attack would have damaged a number of cities, killed millions of people, and might have produced high levels of fallout. The attacked country, faced with such high levels of destruction, might not recognize the intended counterforce limits, either because the damage level was so high or because its information and communications capabilities were inadequate to assess the degree of damage and associated limits.

Another potential source of misunderstanding could be the ambiguous nature of certain actions. For example, a country could increase the alert status of its forces for the following reasons: military prudence; active plans to employ the forces in the near future; or, a desire to communicate seriousness to the enemy. The enemy's reaction will depend on how he interprets the alert. Verbal communication to clarify intentions may not be possible (and may be seen as

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[11] In World War I, French policemen called into duty used tear gas, which the Germans saw as "gas," with the result being widespread use of poison gas.

counterproductive); if communications are possible, they may not be credible.

Note that any escalation calculation requires an assessment of enemy reaction that should be based not only on "objective factors," but also the enemy's character, doctrine, objectives, and expectations. If these factors are assumed or judged incorrectly, then the enemy's reaction will be misevaluated. This is likely to be particularly dangerous in cases where the adversary is judged to have less resolve than he actually has, and in cases where possible reactions are ignored because the decisionmaker has considered the effect of escalation on the enemy from too narrow a perspective. Examples of the latter include cases in which decisionmakers ignore available information and complications due to time pressure and the stress of a crisis or because of preconceived notions about the adversary.[12]

5. Fatalism

Most of the escalation literature deals with highly structural decision processes complicated by poor information and judgments. It can be argued, however, that a more accurate model of some escalation mechanisms is a simpler one: at some point, one or both of the players resign themselves to "fighting to the end." They are insensitive to the subtleties of escalation except to the extent that they affect better outcomes, and they pay little heed to attempts at "bargaining." The Soviet military literature is highly consistent with this image, especially for events beyond limited use of battlefield nuclear weapons.

Soviet doctrine emphasizes that victory is possible, that in war it is the fundamental responsibility of the military to concentrate effort to achieve that victory (however destructive the war); that it pays to strike first and act at all times decisively; and that restraint (e.g., Western-style escalation control) is foolhardy.[13] This is not "just" exhortation; for example, it is likely that the Soviets conclude that their best chance of limiting overall damage in the broadest sense is to act massively and decisively: fine tuning is not likely to work and

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[12] Such conditions are documented in George et al (1971).

[13] See, for example, Lambeth (1978).

could easily backfire by surrendering the critical initiative. It should be noted also that Marxist-Leninist thinking encourages belief that a final all-out conflict is possible, or even likely. Once begun, such a conflict would--in that view--follow the inevitable laws governing war.

6. Physical Communication Problems

Although it might logically be considered a subset of misunderstanding and misperception (subsection 4.), inadequate physical communications can be so important it justifies separate discussion. As discussed by Ikle and others,[14] nations have often been poor at knowing how to terminate conflict. One factor that could be highly important in the nuclear era is the survival of national command authorities and their ability to communicate a sense of limits to their own forces and the enemy. An attack designed to obliterate C^3I would also affect the feasibility of negotiated termination.[15]

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[14] Ikle (1971); Foster and Brewer (1976).
[15] Steinbruner (1981-1982).

III. ISSUES FOR THE RAND STRATEGY ASSESSMENT CENTER

This section describes the following issues, which the RSAC must consider in deciding how to model escalation:

- What *variables* are required to treat escalation adequately?
- What design *requirements* follow from objectives?
- What are the RSAC's *options* in this regard?

VARIABLES TO INCLUDE IN THE ESCALATION MODEL

The previous section's description of escalation suggests that a decisionmaker would be sensitive to the following variables when making an escalatory decision:

1. *Objectives*
   - o Original objectives
   - o Changes in original goals due to:
     - Military costs incurred during the conflict
     - Commitment of international prestige
     - Commitment of national leadership prestige
   - o New goals
     - Not to lose; or, to achieve an "acceptable" outcome
     - New opportunities that arise during the conflict
2. *Likelihood of achieving goals*
   - o Military capabilities
     - Enemy's
     - Own
     - Alliance support for each country
   - o Assessment of enemy (initial and as modified by behavior)
     - Goals
     - Doctrine
     - Adventurousness
     - Limits recognized
   - o Factors that could alter original beliefs

- Demonstration of willingness to escalate and commit forces
- Explicit communications
- Unexpected behavior

o Own character
- Willingness to take risks
- Decisionmaking criteria
- Ability to communicate resolve and to bargain
- Expected effect of escalation on enemy

3. *Risks/potential outcomes*
   - o Escalatory options available to the enemy at each level of conflict
   - o Escalatory options available to the decisionmaker
   - o Potential outcomes

These, then, are factors that must be included in any RSAC model. Although seemingly abstract here, it is important to give these factors specific meaning. Doing so is possible in the RSAC's unique automated war gaming in which, for example, the models producing U.S. and Soviet decisions can reflect alternative behavior patterns.

ADDITIONAL DESIGN REQUIREMENTS

There is a close relationship between the objectives of the RSAC and the requisite features of the escalation model. A careful discussion of what the RSAC objectives can and should be is beyond the scope of this Note.[1] But it is possible to suggest how the potential objectives might determine the way in which escalation should be modeled. We consider five objectives here: (1) plausibility; (2) completeness; (3) realism; (4) operational flexibility and transparency; and (5) reproducibility. There are others as well, but they are not so relevant here.

[1] See Davis and Winnefeld (1983) for discussion.

1. Plausibility

A minimum objective is that the RSAC generate a *set* of plausible scenarios forming a better basis for decision than one or two canonical scenarios. This requires that each decision be based upon plausible criteria and that the initiating scenario also be plausible. If this condition is violated, then surprising or interesting scenarios may be dismissed as too unintuitive to deserve further consideration. A model should produce results in which there is enough confidence to warrant scrutiny of unexpected chains of game steps.

2. Completeness

One difficulty in drawing conclusions from scenarios meeting the plausibility criterion is that there may be no way to establish the relative likelihoods. To a large extent it may be left up to the analyst to make these judgments. This could undermine the value of the entire process if the familiar scenarios were judged to be most likely, and the controversial ones were ignored as improbable. Conversely, if all scenarios were considered equally likely, then worst-case planning might prevail.

A minimum requirement is that the model generating RSAC scenarios be in some sense complete. While it is difficult to be precise about what constitutes completeness, the basic idea is that all classes of scenario important for the analysis at hand should be generated by the model. The analyst's judgment would still be crucial in affixing on weights, but at least there would not be a systematic bias built from the start.

Escalation scenarios depend upon many variables including the initiating scenario, the combat outcomes once the forces are engaged, and the characteristics of the NCA. Here we are primarily concerned with the decisionmaking variables and processes. For decisions in which the decisionmaker could react to the opponent's escalatory action in two or more ways, completeness requires that each way be examined. In the following examples, which were cited earlier, completeness would require that each possible interpretation be examined:

- a change in alert status could be interpreted as a militarily prudent action, a warning, or an indication of an imminent threat; and
- certain escalatory actions either could encourage counterescalation or could convince the enemy to negotiate or terminate the conflict.

This ambiguity of limits may seem self evident, but in practice there will be tremendous pressure to simplify the model by leaving out "crazy" cases. Moreover, the RSAC's emphasis on heuristic modeling makes it easy to omit potentially important cases.

3. Realism

Another feature of the model that may be important is the degree to which the simulation of decisionmaking is realistic (i.e., not only must the events generated be plausible, they must also be reasonably accurate and result from credible processes). The value of the insights gained may depend upon how closely the model reflects how a decision would actually be made--i.e., how well it reflects the reasons. Building a realistic model requires not only identifying the considerations to which a decisionmaker would be sensitive and finding appropriate surrogates, but also developing decision criteria capturing the interactions between the variables and reflecting the decisionmaker's value system.

Looking back over subsections (1.) to (3.), note that to what extent a model is required to be plausible, complete, or realistic will depend upon the question the RSAC is trying to answer. Generating a broad range of plausible scenarios could be useful for improving peoples' intuition about the possible range of challenges and requirements. Completeness becomes important when it is necessary to examine a representative set of the possible scenarios or to judge their relative likelihoods. If asking questions like, "what happens if we change variable x," it will not be possible to get a balanced answer unless the rules that depend on x are complete. How realistic the model

is becomes important when we ask not only "what if," but "why." To answer why something happens when variable x is changed, we must examine the rules or decision criteria that depend on x.

How much can be learned in moving from a plausible model to a more realistic model deserves serious examination. It seems likely that the advantages are fewer than one would originally guess, since escalation has an important element of unpredictability: while certain reactions are more likely for some decisionmakers, opposite reactions are possible for others. Even for a given RSAC Ivan, it will probably be necessary to consider alternatives for certain crucial rules because of fundamental uncertainty. If the range of outcomes is then large, that is, if the effect of this uncertainty overwhelms the other variables (choice of Ivan, etc.), then realistic models may offer little more than plausible ones. To put the matter differently,

- It may be more important to build a model that generates the full range of plausible scenarios than to go on to make that model simulate the decision processes in detail.

Judgments on this matter will have to wait for experience with detailed modeling. Obviously, we would prefer models yielding both plausible and realistic scenarios.

4. Operational Transparency and Flexibility

Two important features of the model may be *transparency* and *flexibility*. In any application of the RSAC going beyond simple scenario comparison, it will be important to examine and understand the decision criteria. This transparency will allow analysts to study such decision criteria and judge whether they are plausible, complete, and realistic. Flexibility is important because experimentation requires that both decision criteria and scenario inputs be varied. One potentially valuable application of the RSAC may be for its users to challenge the construction of the major agents by substituting their own decision criteria and examining the new scenarios generated. This experience could well be more valuable than the scenarios themselves,

since it would be analogous to testing and improving intuition by playing war games with the advantage of explicitly stated assumptions and reasoning.

5. Reproducibility

A basic tenet of the RSAC is that results should be reproducible. This creates some difficult problems in treating escalation because some escalatory decisions depend on assessments of probability and because it will not be practical to run separate war games for each alternative decision rule determining Soviet, U.S., and third nation escalations. We do not discuss this issue in depth here (or the larger issue of how the RSAC will handle uncertainties). However, some of the material in the next section is directly relevant.

RSAC OPTIONS

The RSAC has two major options for modeling escalation. The first option is a rule-based model in which if a certain situation occurs, then appropriate actions are specified. These actions result in a new situation to which the other agent then reacts. This type of model is now used in the Mark II Red and Blue Agents.[2] The second option is the decision analysis model described in the next section of this Note. This type of model is similar to the model suggested for the national command level of the Mark III Red Agent.[3] There is also the possibility of developing a hybrid model in which the two options are combined. After examining the decision analysis model in the next section, the options are considered in terms of RSAC requirements for modeling escalation.

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[2] The model is described in detail in Jones, LaCasse, and LaCasse (1983).

[3] See Steeb and Gillogly (forthcoming).

IV. A DECISION ANALYSIS MODEL OF ESCALATION

CONCEPTS

The concept of escalation ladders and the techniques of decision analysis provide the necessary structure for studying escalation in a formal model.[1] The escalation ladders represent the decisionmaker's understanding of his own and the enemy's strategic options. Figure 1 shows a possible *joint* decision tree for a Red decisionmaker.[2] The tree contains three different types of decision nodes: (1) rectangles are Red decision nodes (since Red is making the decisions there is no uncertainty associated with these nodes); (2) diamonds are Blue decision nodes (since Red can not predict Blue's reaction with certainty, this is a chance node); and (3) circles are outcome nodes. P_k, P_l, etc., are the probabilities of options at the kth, lth, etc., nodes (a more complete notation would index each branch at each node--i.e., P_{k1}, P_{k2}, ...); U_{kl} is the utility to Red of the intermediate outcome resulting from particular decisions at the kth and lth nodes. Once Red or Blue has made an escalatory decision, there is a range of possible outcomes for which Red must estimate the likelihood. It is this uncertainty that is represented by the outcome nodes. In this joint decision tree model, the decisionmaker evaluates his escalatory options, as identified in the escalation ladder, in terms of: the current state of the conflict; how his escalatory decision might affect the outcome of the conflict; and how such a decision might affect the opposition's escalatory decisions.

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[1] There are definite problems with approaches based on escalation ladders for which the rungs are actions rather than levels of conflict. For example, the *order* of rungs has to be fixed--even though actions escalatory in one context may be deescalatory in others. Our approach on this has been to use relatively coarse ladders for which actions (e.g., nuclear preemption) *imply* levels of conflict.

[2] Although unconventional in strategic analysis, joint escalation ladders (i.e., ladders combining decision points for Red and Blue) have numerous advantages over the lone or parallel ladders used in other studies.

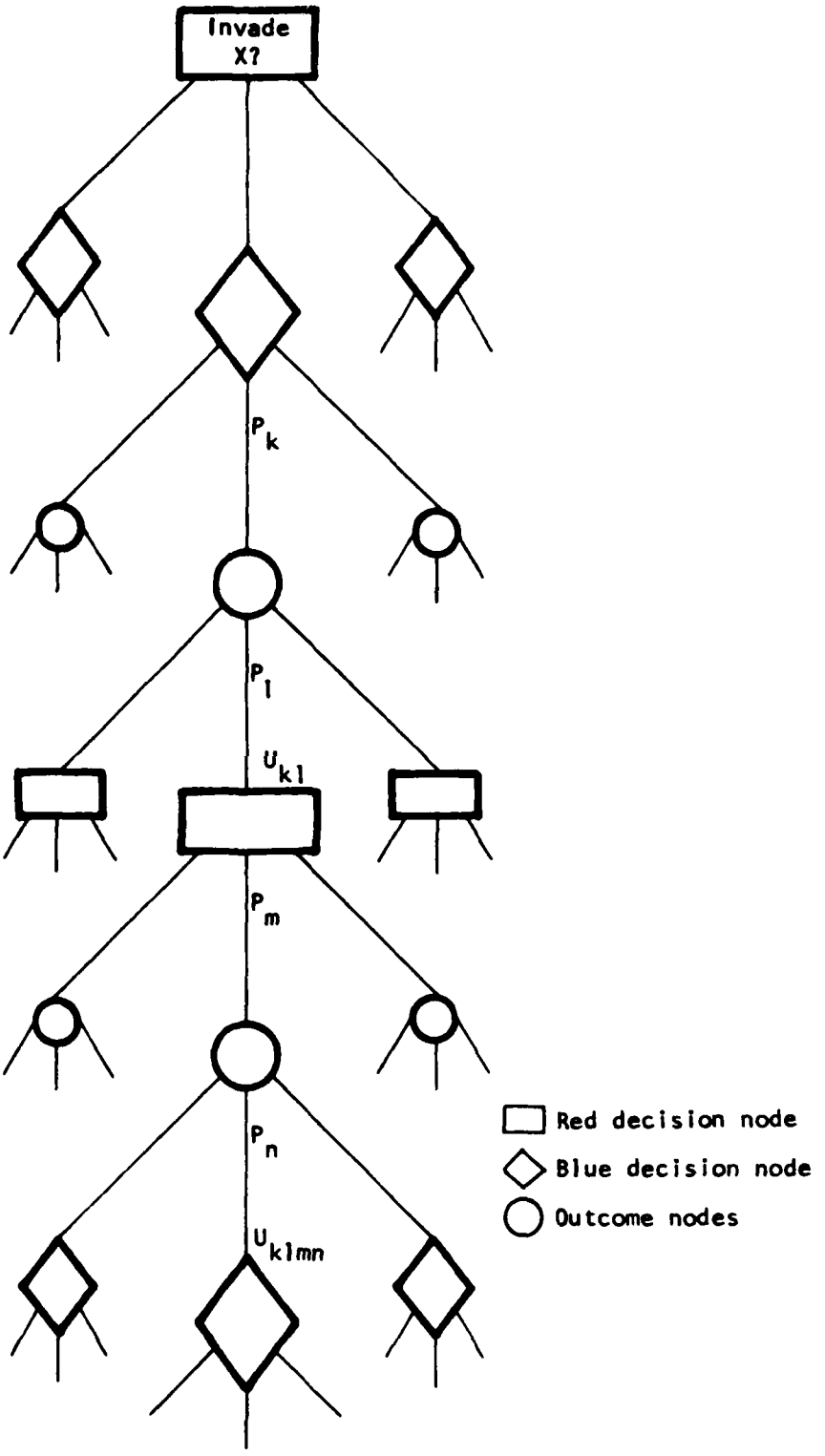

Fig. 1--A joint decision tree for Red and Blue

In the most general formulation the decisionmaker would make a choice from an entire escalation ladder of options, ranging from deescalate to the full use of available force. Red knows the rungs of his own escalation ladder, and assumes he knows the rungs of Blue's ladder. Let the ladders run from rung 0, no conflict, to rung M for Red and K for Blue. The highest level for each agent is assumed to be general nuclear war, but the number of intermediate steps may not be (indeed, probably is not) equal for the two agents. As discussed in Stan and Davis (forthcoming), the number of rungs may be treated as a function of the participants' capabilities, objectives, and doctrine, none of which are constant.

The probabilities assigned to the opponent's options, represented as branches at the opponent's decision nodes, can be constructed to include the interactive component of escalation. Furthermore, since these probabilities are conditional probabilities, which depend upon what has already happened in the conflict, they can be constructed to take account of changing stakes and objectives of the conflict. The specific characteristics of the adversaries, including their military capabilities, political objectives, and behavioral or doctrinal features, are required to estimate the decision probabilities, outcome probabilities, and the values of the outcomes. Assuming for the moment that these quantities are known and can be treated within set parameters, the decision calculus is explained below.

Given this structure for analyzing his decisions, how should Red make his choices? The answer depends on how far Red is able or willing to look confidently into the future. In principle, the Red decisionmaker could trace the possible course of the conflict from its initiation to its termination along all possible paths. In practice, a decisionmaker may be capable of looking only a few moves into the future. How far the decisionmaker should look ahead is a judgment call that must be built into the model. (How the decisionmaker's view of escalation affects the length of the "look-ahead" is discussed in the next section.) If the decisionmaker does not look ahead to the point of war termination, then a utility value would have to be assigned to interim states of conflict, as well as to the final states. Once the

length of the look-ahead is decided, the decision on whether to begin a conflict can be determined by calculating the expected utility of the conflict. Starting at the bottom of the decision tree (as defined by the end of the look-ahead), the expected utility of a chance node is defined as the probability of an outcome times the utility of the outcome, summed over all the branches at the node. This expected utility can then be used to represent the utility of the node, and the expected value of the next higher node can be calculated using the same procedure. When a Red choice node is reached in working up the tree, Red chooses the largest expected value of the nodes that are directly below it. This procedure is carried out until the top of the tree, i.e., the decision of whether to begin a conflict, is reached. If the expected utility of the conflict is greater than the utility of the status quo, which can be set to zero, the decision would be to begin the conflict. If, for example, the look-ahead for Red in Fig. 1 was to go as far as the first Blue response, then the expected value of the conflict would be equal to

$$\sum_k P_k \cdot \left(\sum_l P_l \cdot U_{kl} \right).$$

If in the look-ahead Red includes its response to Blue's reaction, then the expected value equals

$$\sum_k P_k \cdot \left[\sum_l P_l \cdot \underset{m}{\text{MAX}} \left\{ \sum_n P_n \cdot U_{klmn} \right\} \right]$$

The expected values can, in theory, be calculated for look-aheads of any length. Although the closed form solutions quickly get increasingly complex, this method of "folding back the tree" can be used for reducing trees of any size without sacrificing substance.[3]

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[3] Jonathan Cave of Rand is now working on an alternative to the particular "backwards induction approach" used here. In his approach, an opponent's assured utility structure is used to *derive* what appears in Fig. 1 as the probabilities of different opponent choices. This approach has definite theoretical advantages with respect both to clarity and learning (actual opponent decisions can be used to adjust his estimate utility structure). The approach also has its own problems, including that of infinite regress (Red's model of Blue's model of...), but may prove valuable.

If Red starts the conflict and Blue responds, then Red may have to decide whether to escalate. Red would perform a look-ahead and calculate an expected value using essentially the same procedure used before. The expected value changes, since now it depends only on the part of the tree below the decision node. If the original look-ahead did not include the entire tree, then this look-ahead will also include new information that will contribute to a change in the expected value. The decision criteria will also have changed, since the expected utility comparison is no longer relative to the previous status quo, but to the current state of the conflict, including losses and gains incurred until the point of decision.

WHAT IS NECESSARY TO IMPLEMENT THE MODEL?

The joint decision tree model provides a structure capable of including much of the information that is necessary to analyze escalation. The issue is how to include this information in the model. Specifically, how can the probabilities and values of outcomes be determined?

1. Probabilities

For each Blue decision node the Red decisionmaker must estimate a set of probabilities describing his expectations about Blue's action, i.e., Red must estimate the likelihood of Blue choosing to escalate to a specific level of his escalation ladder. Each Blue decision node can be partially characterized by: (1) the current level of conflict, including force alerts and mobilizations, communications, etc.; (2) the losses incurred by each side; (3) the outcome of the conflict if there is no escalation; (4) the cooperation expected or demonstrated by each country's allies; and (5) the crisis and escalation stability of the balance. To estimate the probabilities, it is also necessary to describe the type of Blue agent Red believes he is facing, which will be a function of such variables as: (1) pre-conflict assessment of Sam; (2) actions during conflict that either reinforce or weaken previous estimates of Blue character, such as military or diplomatic actions; and (3) understanding of Blue's doctrine or strategy, including Blue's view

of Red. Given this information, one way to determine probabilities for Blue's actions is to ask Soviet specialists how the Soviets would judge the likelihood of each Blue option.

Because at least two types each of Red and Blue Agents will be studied, each decision node must be considered for a number of cases. The information that describes the status of the conflict depends only on the decision node, but the information about Red's understanding of Blue depends on which agents are being examined. This understanding depends on the decision node, since information from the conflict could lead to a Red reevaluation. Red's pre-conflict understanding of Blue can be varied while holding the status of the conflict fixed: for each Red vision of Blue there will be a different estimate of the probabilities at each node.

2. Utilities

A basic element of decision theory is the idea of utility values: values representing the relative desirability of alternative outcomes.[4] There is likely to be resistance to assigning numerical utilities to outcomes. This reluctance may be diminished somewhat once it is realized that utilities can be constructed to reflect beliefs about a decisionmaker's willingness to gamble on alternative outcomes. It is not necessary to make statements like "this outcome is x times as bad as that outcome." Methods for constructing utility functions have been studied extensively by decision analysts. An area for future study could be to determine how best to apply these techniques to the problem at hand.[5]

The problem is to break questions down into digestible and understandable pieces. For example, one could deduce utilities for model purposes without ever referring to them directly by asking questions such as: "suppose the outcome of current strategy will be military defeat in Europe with the Soviets reaching the channel in two

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[4] See Keeney and Raiffa (1976).

[5] The reality of implicit utilities is easily demonstrated: if general nuclear war were *absolutely* unacceptable, then we would have to surrender whenever war approached the nuclear barrier--at least in a "rational" calculation. In fact, the United States would take substantial risks regarding general nuclear war rather than submit.

weeks or less, and suppose that escalation to battlefield nuclear weapons would lead either to a ceasefire with boundaries at...(probability P); or to further escalation to general war (probability 1-P). How large would P have to be in order for escalation to be attractive?" This question is simplified, of course, but the point is that the objectionable aspects of specifying utility values can to a large extent be averted by translating the problem into queries about subjective indifference points for intuitively understandable tradeoffs.

V. USING DECISION ANALYSIS TO MODEL ESCALATION

The preceding section described how decision analysis is theoretically well suited to modeling escalation in general. This section examines how to build particular aspects of escalation, such as asymmetries between the decisionmakers, pressures to escalate, the interaction between decisionmakers, and misunderstandings, into RSAC models.

DECISIONMAKER CHARACTERISTICS

1. Types of Decisionmaker

Two basic characteristics distinguishing different RSAC Ivans are their propensities for adventurous action and risk-taking. These behavioral descriptions are frequently used and evoke an image of a certain type of decisionmaker. Yet to develop consistent models of the Red Agents it may be useful to distinguish between these characteristics in a precise manner. One approach for distinguishing the agent's characteristics and including them in the model is presented below.

The adventuristic Ivan can be taken to be one relatively less sensitive to the information available for making decisions. This results in a decisionmaking style that may: (1) ignore or pay relatively little attention to objective information on the type of Sam Red is facing, e.g., changes in Blue's alert status and other indicators of Blue resolve; (2) overlook some potential of Blue's capabilities for military action; (3) underestimate the potential for Blue's alliance to act cohesively and overestimate the Warsaw Pact's cohesiveness; and (4) overlook low-probability events generally, even if they would have very negative consequences. Thus, the adventuristic Ivan would fail to use all information available--he would focus on benefits rather than risks.

The risk-taking aspect of behavior could be taken to mean any of several things. The RSAC model will probably want to interpret risk-taking as meaning the willingness to accept higher risks even when

consciously aware of them. For model purposes, this would translate into different relative utilities than those of a non-risk-taking Ivan. To summarize then, an adventurous Ivan might do a bad job of calculating probabilities of bad events while the risk-taking Ivan (who might also be adventurous) would be prone to risky actions even if his calculations were accurate.[1]

2. Decisionmaker's Depth of Focus

How does the decisionmaker decide whether or not to escalate? In theory, evaluation of the decision tree would begin at its end, the expected utility would be calculated, and a decision made. But this may not be a good reflection of how the decisionmaker considers the decision. As discussed earlier, the decisionmaker may not consider the full chain of actions that could follow an escalation for at least two behavioral reasons. First, the number of paths is enormous and the feasibility of considering the full range of outcomes for all paths dubious. Still it may be that folding back the tree provides a good approximation of the values that would be associated with each branch. Second, and probably more important, the decisionmaker may not envision escalation as an *open ended* set of actions and reactions, but rather as a *limited* number of action-reaction cycles. If the decisionmaker bases his choice on the state of the conflict one or a few escalations into the future and not on the true conflict termination conditions, then expected utilities should be calculated by folding back only that portion of the tree within the decisionmaker's consideration. This requires assigning interim utilities to the states of conflict as well as to the conflict outcomes. This does not mean the decisionmaker totally ignores all information which is not required to evaluate the near term effect of escalating. For example, if the nuclear balance is considered more stable, then the decisionmaker might be less risk-averse in pursuing conventional actions that could possibly lead to nuclear war. This would be reflected in the interim utilities (which reflect

[1] See Kahneman and Tversky (1978), pp. 263-291, for a discussion of how people choose between risky prospects in ways that violate fundamental assumptions of utility theory. In our terminology, we could say they do the calculations poorly, but in fact the issue is deeper--their decisions are "irrational." See also Raiffa (1968).

the decisionmaker's assessment of expected future as well as present conflict).

Some of these concepts can be clarified by considering the decision trees in Fig. 2. Decision tree A represents the true complexity of the world in which escalation may be open-ended, and the decisionmakers face binary choices.[2] The "x + 1" labels on the branches indicate the levels of escalation that are available to the decisionmaker represented by the node. The tree is drawn for a Red decisionmaker involved in a conflict at level x. If the Red decisionmaker envisions escalation as an action with no reaction, then his model can be represented by tree B, where U_1 and U_2 are the utilities Red assigns to the conflict if he does or does not escalate, respectively. Similarly, if the decisionmaker imagines escalation to be a single action-reaction cycle, then he is using a decision tree like tree C.

If Blue matching escalation is not considered, then Red would compare U_1 to U_2 in tree B. We expect that $U_2 > U_1$ in almost all cases, and that Red would therefore escalate. (An escalation expected to have limited success and negative collateral effects could have U_2 less than U_1). If Red assumes that Blue will counter by matching his escalation, then the decision depends upon a comparison of U_{11} and U_{22} in tree C. If Red does not know what Blue's reaction will be in the latter case, but still only considers a single action-reaction cycle, then the appropriate comparison is between the expected values of the interim utilities, i.e., $P_{11}U_{11} + P_{12}U_{12}$ compared to $P_{21}U_{21} + P_{22}U_{22}$. In a more general tree with i escalatory options the comparison would be between

$$\sum_i P_{1i}U_{1i} \text{ and } \sum_i P_{2i}U_{2i}.$$

If the Red decisionmaker looks further into the future, then the comparison would be between expected interim utilities as described previously.

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[2] Figure 2 assumes Red will not escalate beyond Red's level. Also, of course, decisions do not have to be binary.

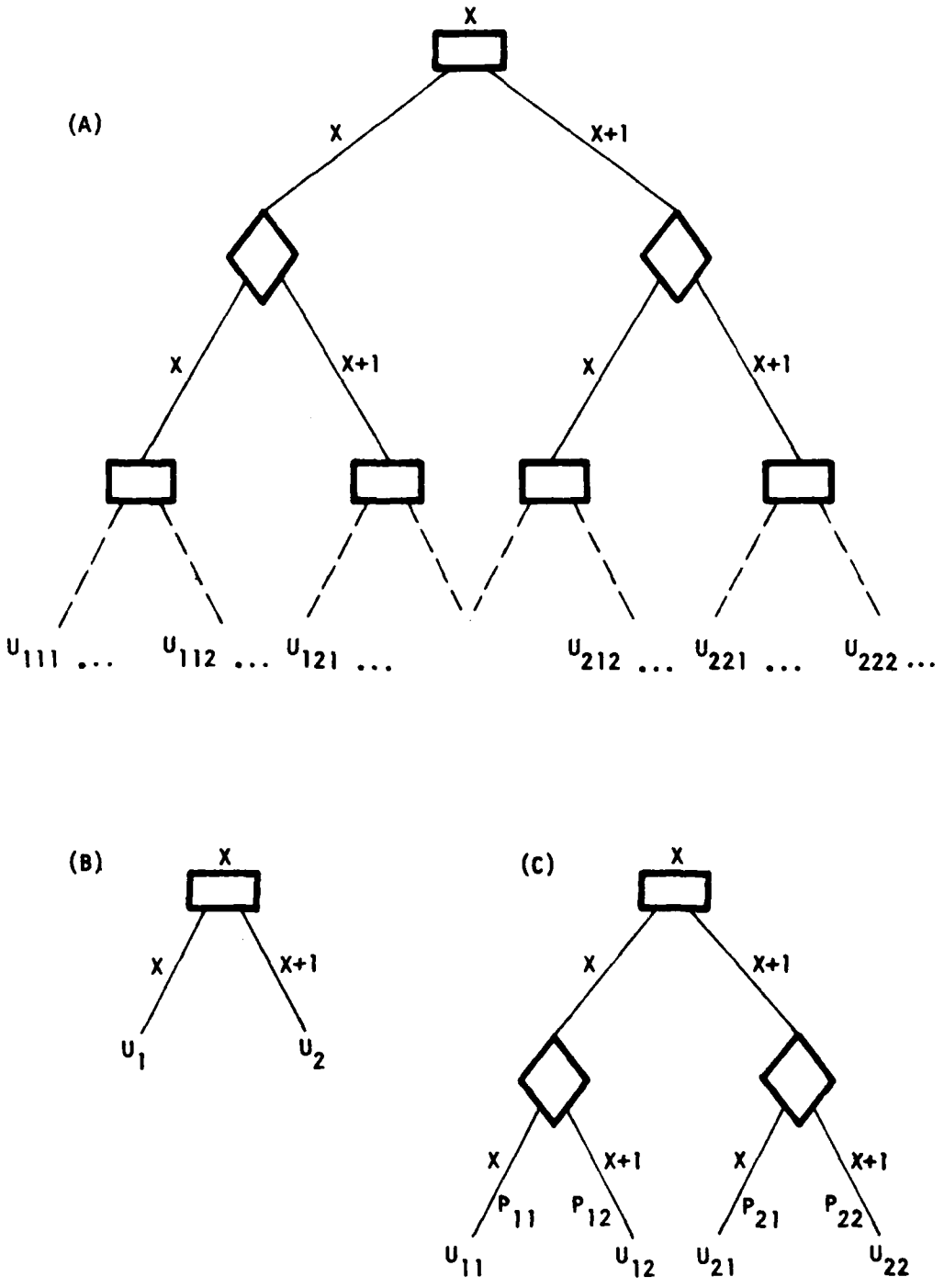


Fig. 2--Alternative Red decision trees for a Blue that may or may not match Red's escalation

OTHER ASPECTS OF DECISIONMAKING

Section II identified a number of aspects of escalation, including bargaining and several mechanisms for escalation to "get out of hand." In what follows, we show how those matters can be treated with a decision analysis model.

1. Bargaining and the Desire to Win

An important component of bargaining is the communication of resolve. The intention of the communication is to alter the enemy's expectations about your willingness to escalate even further. The higher the enemy's estimate of future counterescalation, the less attractive it will be for him to escalate. We can understand this in terms of Fig. 2's decision tree C in the following way. Assume Red believes escalation will show Blue his determination to win. If he believes that Blue will be impressed by his resolve, and therefore be less willing to challenge him, Red will estimate $P_{22} < P_{12}$.[3]

2. The Stakes Change During the Conflict

At each decision node Red compares his options to the current status quo, not the pre-conflict status quo. Losses of troops and equipment and damage to the leader's or country's prestige would be factors that contribute to lowering the utility associated with the current status quo. So if a conflict is going poorly, options and outcomes unacceptable before the conflict began might now be pursued, since the cutoff for deciding to escalate would have shifted downward. Conversely, if gains have been achieved the cutoff would shift upward.

3. Instabilities

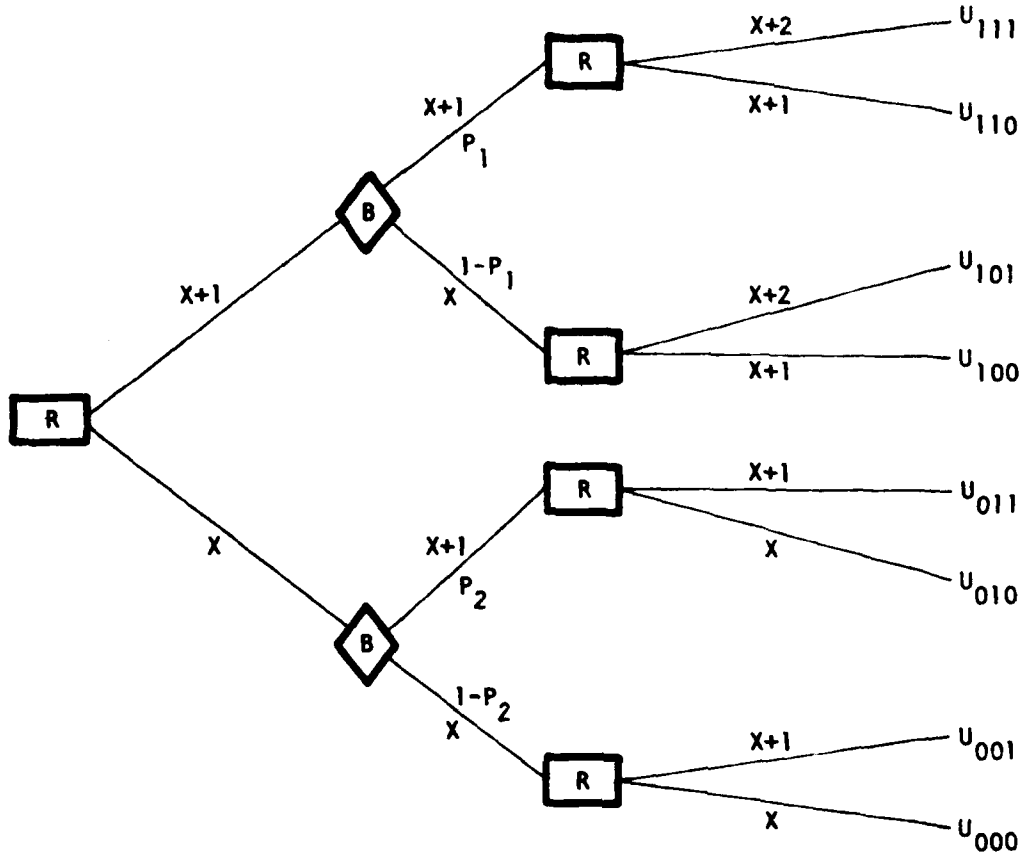
The effect of crisis instabilities on escalation decisions can be completely accounted for in the decision analysis formulation. The advantage of escalating first rather than second is included in the utilities, which are then folded back into the expected utilities. It

[3] He will also ignore the likelihood of Blue escalating beyond Red's level, to x + 2. Figure 2 is consistent with that image of Blue.

is difficult to follow the impact of the instability on the decision calculus because of the large number of variables. The following example sheds some light on how decision analysis captures a situation in which a decisionmaker escalates because he thinks the enemy will escalate, and it pays to act first. Unfortunately, it is impossible to isolate the effect of the instability without a number of restrictive assumptions. Consider the case in which the conflict is at level x, and Red is considering escalation to level x + 1 (see Fig. 3). In the utility notation "1" represents a decision to escalate, "0" represents a decision not to escalate. The order of the subscripts represents agent moves starting with Red. So U_{110} is the state in which Red initiated escalation to x + 1, Blue then matched the escalation, and Red did not escalate further. Similarly, U_{011} is the state in which Red did not escalate, Blue escalated to x + 1, and Red matched the escalation. We say *there is a structural crisis instability if* $U_{110} > U_{011}$.

Let us now make the following somewhat arbitrary, but reasonable, assumptions:

a. $U_{000} = 0$, and all other utilities are negative.
b. Red will not escalate to x + 2. This could be because Blue's reaction would be too severe or because it is not necessary, as in the U_{101} state where Blue did not escalate to x + 1.
c. It is better for Red to match Blue's escalation than not to match it, i.e., $U_{011} > U_{010}$. Given these assumptions the decision tree can be folded back one node as shown in Fig. 3.
d. $P_1 \geq P_2$. This is a reasonable assumption, although not necessarily true. If Red is afraid Blue is going to escalate, he probably thinks Blue would be even more likely to retaliate than to initiate the escalation. (Of course there is the other case in which Red believes escalation would convince Blue to negotiate or terminate the conflict.) For this example the more conservative assumption, $P_1 = P_2$, is sufficient.



Above tree folded back under assumptions given in the text

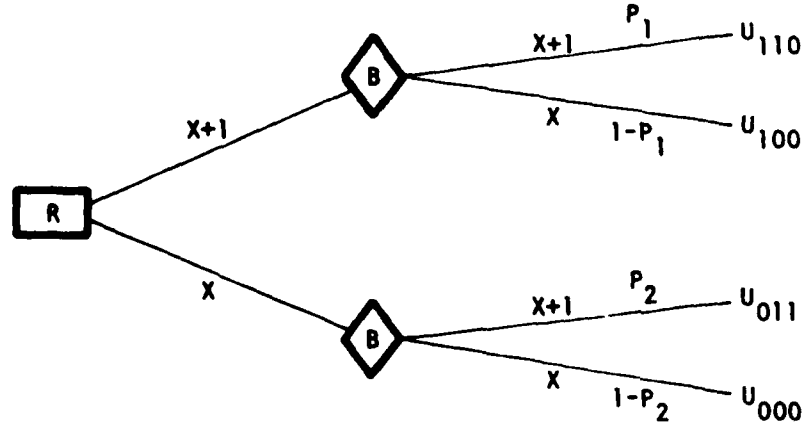


Fig. 3--Decision trees for understanding crisis instabilities

The decision criterion is:

if $P_1U_{110} + (1 - P_1)U_{100} - P_2U_{011} > 0$, then Red should escalate.

Using $P_1 = P_2$, this becomes:

if $P_1(U_{110} - U_{011} - U_{100}) + U_{100} > 0$, then escalate.

This can be rewritten so that Red should escalate if

$$P_1 > -U_{100}/(U_{110} - U_{011} - U_{100}) = P^*.$$

If there is no structural instability, then $U_{110} = U_{011}$ and $P^* = 1$. In this case, Red would never see an advantage in escalating first. If there is an instability, then there would always be a P_1 for which Red would prefer to initiate escalation. The greater the advantage of going first, that is, the larger $U_{110} - U_{011}$, the lower the threshold for escalating. It is in this sense that P^* can be thought of as a measure of the instability.

4. Misperceptions and Misunderstandings

A misunderstanding of what limits are recognizable can be modeled by having Red imagine that Blue's escalation ladder is different from Blue's true escalation ladder. In the example used above, if Red thinks Blue's escalation ladder does not include a theater nuclear rung, then Red might not consider the TNF option until he thought the use of central systems was very likely. If Blue's true escalation ladder were used, the decision to use TNF might be taken earlier.

Misunderstanding which limits are available is one of many ways of misperceiving the enemy. The more general issue of how the enemy will react to an escalation should also include consideration of his resolve, willingness to take risks, doctrine, expectations, and objectives. Having decided on these characteristics, it is then possible to estimate the probability of certain reactions. If the probabilities are

estimated with the wrong enemy decisionmaker in mind, then undesired outcomes are more likely.

The case of actions open to multiple interpretations, some of which are escalatory, can be modeled by adding another uncertainty node (Fig. 4). For example, assume an action has two possible interpretations, escalatory and not escalatory, and that Red realizes that this ambiguity exists. Then when considering the action, Red needs to estimate the probability that Blue will find the action escalatory; the probabilities of Blue reactions can then be estimated conditional on Blue's interpretation. If Red is modeled to ignore the ambiguity, then the additional uncertainty node would not be included, which could result in misjudgments by Red.

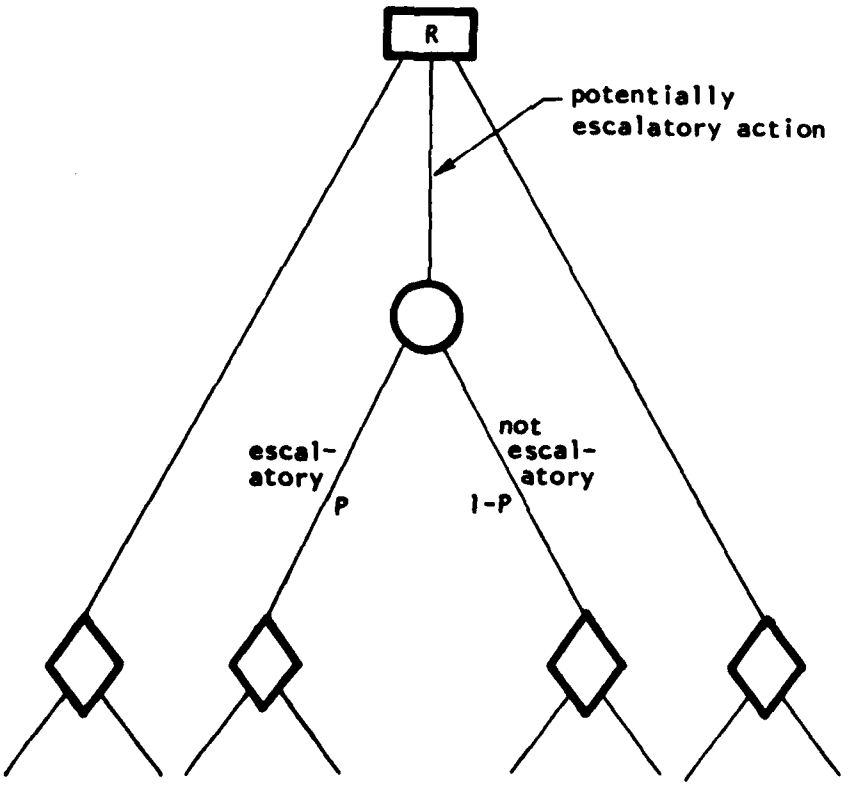


Fig. 4--Uncertainties in perceptions about escalatory intentions

None of this should be read to mean that treating misperceptions and misunderstandings will be easy, but rather to suggest that they can, in principle, be modeled. Indeed, doing so is a major emphasis in RSAC work because these matters are so critical in actual problems.

5. Fatalism

If one of the parties concludes that "the great war is here," he will probably be insensitive to the possibility of deescalation. He will probably assume the other side will escalate even if he does not. He will probably not consider certain steps of the escalation ladder, instead preferring to act decisively. He will not be likely to show restraint if doing so may surrender an important initiative.

6. Communications

The effect of poor communications on escalation can be treated in the same way as can misunderstandings and misperceptions. However, there should be explicit linkage between, for example, the conditions of war and the quality of information exchange possible and the likely character of decisionmaking.[4] As communications degrade and key leaders die or find themselves disconnected, the likelihood and feasibility of cautious escalation control or bargaining would be reduced substantially. Making such issues will require extensive research.

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[4] Then Secretary of Defense, James Schlesinger, is said to have once questioned the credibility of a Soviet first strike on Washington because that might "leave them to the tender mercies of CINCSAC."

VI. COMPARISONS OF DECISION ANALYSIS AND THE HEURISTIC APPROACH

CONCLUSIONS ABOUT DECISION ANALYSIS

The decision analysis model appears to be capable of incorporating virtually all of the important aspects of escalation. Because the structure of the model is well matched to escalatory decisionmaking, information can be built into the model explicitly. For example, if it is believed that escalating will change the enemy's expectations about the future of the conflict, then the probability estimates of the enemy's reaction can be adjusted; if an action is known to have more than one interpretation, then a special uncertainty node can be included in the model. The strengths of decision analysis are its ability to distinguish between the aspects of escalation in a precise manner, and the ability to mirror, at least partially, the way in which decisionmakers implicitly consider their options.

Problems with the decision analysis model exist because a great deal of information must be included in the probabilities and utilities:[1]

1. Probabilities will be difficult to estimate because they include information about a variety of variables, some of which may have opposite influences. Similarly, utilities will be difficult to estimate because they will depend upon a number of competing variables. The problems of estimating utilities will be complicated further because the situation for which analysts must make estimates are extremely unfamiliar. Techniques for constructing utility functions have received much study, but the confidence people would have in their estimates would necessarily be limited by their experience (although the importance of accurate estimates could be tested by sensitivity analysis).

[1] There is also widespread hostility toward decision analysis when it involves assigning utilities to matters such as nuclear war.

2. Transforming the judgments about escalation into numbers reduces the transparency of the model. This shortcoming can be reduced if the analyst carefully documents the reasons underlying probability and utility assignments. At a minimum, explanation of why a probability is greater or less than a corresponding estimate needs to be obtained.
3. The flexibility of the model will be limited by the difficulty of translating disagreement about a potential decisionmaker's behavior into numbers. Values will be hard enough to estimate in the first place, but at least the juggling of many variables can be done consistently while the analyst is immersed in the estimation process. On-line adjustments by those unfamiliar with the system promise to be significantly more difficult.[2]

THE ALTERNATIVE: HEURISTIC MODELING

The alternative to decision analysis considered here is heuristic rule-based modeling centered around "production rules" in the form "If...(some condition)..., then...(some action)." Most elements of the RSAC system are indeed based on such models (Davis and Winnefeld, 1983; Steeb and Gillogly, forthcoming).

The strengths and weaknesses of rule-based models and decision analysis models are almost opposites. The former (as represented by the RSAC's Mark II system in 1982), does not allow *explicit* uncertainty--a basic component of escalation. It uses best estimates of enemy behavior in look-aheads to examine the future implications of choosing an action; uncertainty about enemy behavior is not explicitly taken into account. It is, of course, possible to develop rules that reflect the anticipated risk: the higher the risks associated with an option, the more stringent the rules for choosing it. But this method would seem necessarily to be ad hoc rather than formal decision analysis. The size of the anticipated risk is not identified by the model, and the additional increment of caution resulting from more stringent

[2] Another problem with decision analysis is, of course, that some important decision points or alternatives may be omitted. That, of course, is true of competitive approaches as well.

requirements for action rule choice will be difficult to estimate. A related question is whether a model that uses best estimates can be constructed to give the same results as an uncertainty model. Since the latter model comes closer to representing how escalation decisions are made (albeit not necessarily with "rational" utility functions), the potential equivalence of the models should be studied.

The advantages of the heuristic, production-rule model include its transparency and flexibility. The "if-then" type rules are relatively easy to understand (although their relationship to the mechanisms of escalation may or may not be clear), even when there are a number of nested conditional statements preceding the action statement. Changing or adding a rule should not be difficult, since the variables describing the situation and prescribed action are written using familiar terms. Another major advantage *may* be a kind of realism: it is not clear how sophisticated or rational decisionmaking on escalation actually is, and it may be more appropriate for the RSAC to go directly to "bottom line rules of behavior," even if those rules might, upon further analysis, appear to be irrational or at least nonoptimal by many criteria.[3] The RSAC plans to explore these tradeoffs in more detail in 1983.

The advanced, Mark III, version of the RSAC Red and Blue Agents will have the capability to examine decision trees with branches assigned subjective probabilities.

The two approaches probably differ relatively little in their ability to generate plausible scenarios. The production rule model may have an advantage because: (1) not including uncertainty does not undermine the plausibility of the decision criteria, since each of the possible options should be plausible; and (2) the easy way rules can be understood and examined should make it possible to ascertain with greater confidence whether the decision criteria are plausible. It should be equally possible to build complete rule sets for the two models, since this will depend on the ability of the analyst to determine which potential decisionmaker's reactions should be modeled, but not on the structure of the model.

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[3] Usual heuristic modeling is, on the other hand, *less* realistic than decision analysis in its failure to consider uncertainties and the role of odds.

Which escalation model is better suited to the RSAC will depend upon whether the greater transparency and flexibility of the production rule model is more important than the structural advantages of the decision analysis model. This tradeoff will depend in part upon the type of questions that the RSAC is studying. But if it is true that, due to the large unpredictable component of escalation, little more can be learned from realistic models than from plausible models, then the production rule model has major advantages.

A POSSIBLE HYBRID APPROACH

Even if their simplicity and directness make heuristic rules the preferred approach for the basic RSAC model, decision analysis should not be neglected. The decision analysis model can be useful in defining and clarifying the application of escalation theory to the situations that the RSAC is examining. The rigor imposed by the decision analysis approach can improve the understanding of the escalatory process by requiring that: (1) the potential limits to a conflict can be studied; (2) the variables to which the decisionmaker is sensitive are properly defined; and (3) the ways in which escalation can affect the decisionmaker's choice of options are identified. A better understanding of these considerations should be useful in improving the production rule and in checking for completeness. Indeed, it is unclear that a good alternative exists if one wants to subject the production rules to such scrutiny.

A final decision on the RSAC escalation model (or models) will require further study of the type of problems the RSAC should examine. This study should not only consider the type of questions to be investigated, but also the experimental design issues. Then it will be possible to specify more exactly the requirements that the escalation model must satisfy. We suspect, however, that the RSAC's Red and Blue Agents will use heuristic rules for deciding which alternatives to choose in decision trees; there will probably be no explicit use of utility sanctions except for background research.

APPENDIX

BACKGROUND ON THE RAND STRATEGY ASSESSMENT CENTER AND AUTOMATED WAR GAMING[1]

The Rand Strategy Assessment Center is an ambitious multiyear effort to improve the methods by which the United States analyzes and reviews military strategy for potential large-scale conflicts. The RSAC program is the result of DoD initiatives late in the 1970s, initiatives largely influenced by the desire to imbed strategic *nuclear* analysis in a richer context than that permitted by the traditional "exchange calculation" approach. As a by-product of the effort to build such a context, the RSAC can, in principle, treat a broad range of conflicts ranging from U.S.-Soviet confrontations in third areas to full-scale prolonged nuclear war. It will take several years to approach the RSAC's potential in this regard, but progress is now rapid.

As discussed early in the RSAC effort, the concept of replacing the human teams of traditional war games with computer automatons holds out great promise. Indeed, it seems likely that only by such a procedure would it be possible to gain enough control over the variables of war games to permit reproducible, transparent, and rigorous *multiscenario* analysis.

Automated war gaming is an analytic approach with the same structure as classic war games, but with human players complemented by or replaced to a large extent by computer models acting as automatons or "agents." Thus, we refer to the "*Red, Blue, and Scenario Agents*," the automatons representing the Soviet Union, United States, and third countries, respectively. These automatons (or computer models, to be less pretentious but also less colorful) cannot, of course, be reliable predictors of national behavior--there are fundamental uncertainties that no amount of research can eliminate. Thus, we work with *alternative national personalities*, referring to Ivan 1 and Ivan 2, Sam 1 and Sam 2, etc.; similarly, we have rule sets for "reliable allies,"

[1] The material here is extracted from Davis (1982).

"initially reluctant allies," etc. We program the various models in artificial-intelligence languages designed to maximize transparency of the rules by allowing the analyst to interrogate the system about the reason for an automaton's decision, and to have the system respond by displaying the relevant rules in an English-like language. If the analyst does not like a given rule, or has discovered a mistake, he can change the rule interactively.

A powerful feature of our approach, one that tends to distinguish artificial intelligence modeling from other forms, is the use of *heuristic rules*--i.e., individual rules that need not be part of a cosmic theory, and which may not even be universally valid. It has become increasingly apparent to researchers in this area that one can often go further faster using a heuristic approach than attempting to derive that cosmic theory first.

In addition to Red, Blue, and Scenario, the RSAC system includes a Force Agent that keeps book on forces worldwide and describes the expected results of conflict upon demand. The Force Agent relies upon numerous individual combat models, many of which are currently being improved. Figure A.1 illustrates how an RSAC war game proceeds, and suggests by its form that Force Agent, unlike the others, does not make decisions. Rather, it is a service agent. In fact, one can look at Scenario Agent similarly. Scenario Agent does not describe third-nation behavior in the same detail as that provided by Red and Blue; instead, it essentially keeps book on the scenario context and adjusts that context as the game goes on in ping-pong fashion between Red and Blue.

RSAC war games employ human technicians and analysts who can intervene at any move in the game to correct glitches, overrule automatons, or provide unmodeled information. Preferably, however, not much intervention is necessary; instead, the analysts explore issues by rerunning a game with different inputs. The result is a new scenario with new outcomes. Note that by contrast with traditional analyses, *the scenario is an output rather than an input* in RSAC war games. This means that an analyst wishing to have the RSAC system produce a canonical scenario must spell out a lengthy set of assumptions, and tune those assumptions until he gets the results desired. Because of this, we often refer to the automated war gaming as an assumptions trap.

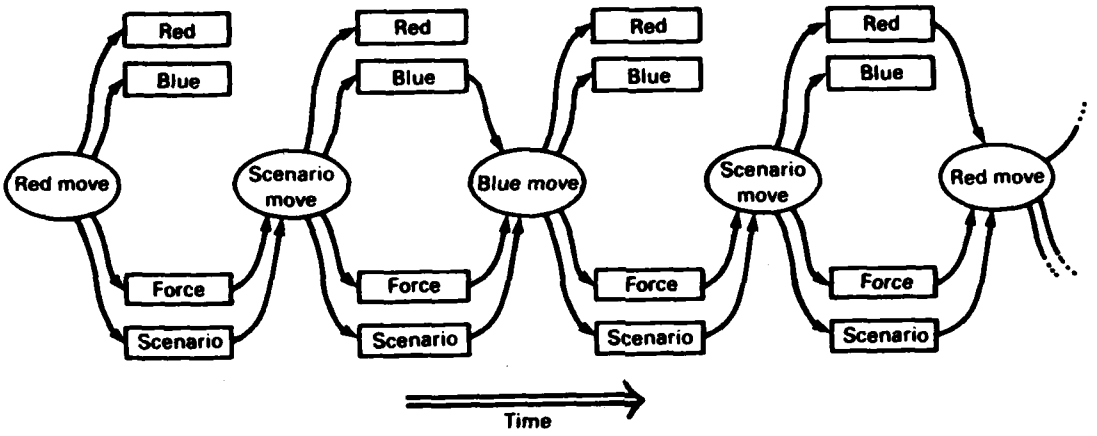

Fig. A.1--Move sequence and information flow in RSAC automated war games

There is another aspect of the RSAC system to address and that is the RSAC's emphasis on multiscenario analysis. It is not our purpose to develop a computerized system for running individual war games, but rather to seek the capability to examine *large numbers of war games* to better analyze the adequacy of alternative forces and strategies. This is a fundamental departure from traditional analysis, which emphasizes "best estimate" planning factors and specifies one or a very few planning scenarios at the outset. In our approach, we want to address uncertainties in such variables as: (1) Soviet behavior, (2) U.S. behavior, (3) third-country behavior, (4) force levels, (5) strategies, (6) details of initial setting, and (7) outcomes of certain types of key battles. How one might hope to digest and make use of the data from such multiscenario studies is a very difficult issue that will be discussed elsewhere.

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